## Unit
## 05

# GRAVITATION

**Introduction**

In this unit we learn about law of gravitation, mass of earth, variation of g, motion of artificial satellite.

**Q1. Who is the first man who gave the idea of gravity?**

**Ans.** The first man who gave the idea of gravity was "Isaac Newton". It was an evening of 1665 when he was trying to solve the mystery why planets revolve around the Sun. Suddenly an apple fell from the tree under which he was sitting. The idea of gravity flashed in his mind. He discovered not only the cause of falling apple, but also the cause that makes the planets to revolve around the Sun and moon around the Earth.

**Q2. What is meant by the force of gravitation? Also explain the law of gravitation.**

**Ans. The force of Gravitation**

Newton gave the idea that there exists a force due to which everybody of the universe attracts every other body. He named this force the force of gravitation.

**Law of Gravitation:**

"Everybody in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers."

**Mathematical Form**

Consider two bodies of masses "$m_1$" and "$m_2$". The distance between the centers of masses is "*d*" as shown in figure. According to the law of gravitation, the gravitational force of attraction "F" with which the two masses "$m_1$" and "$m_2$" separated by a distance d attract each other is given by:

$$F \propto m_1 m_2 \quad ..........(i)$$

$$F \propto \frac{1}{d^2} \quad ........(ii)$$

By (i) and (ii)

$$F \propto \frac{m_1 m_2}{d^2}$$

$$F = G\frac{m_1 m_2}{d^2}$$

Here 'G' is constant of proportionality is called universal constant of gravitation. In SI Unit its value is 6.673 x $10^{-11}$ $Nm^2Kg^{-2}$ and is remain same everywhere.

**Q3. Why we cannot feel the force of attraction between the objects around us?**

**Ans.** Due to small value of G, the gravitational force of attraction between objects around us is very small and we do not feel it. Since the mass of Earth is very large, it attracts nearby objects with a significant force. The weight of an object on the Earth is the result of gravitational force of attraction between the Earth and the object.

**Q4. How does Law of gravitation relate with third Law of motion.**

**Ans. LAW OF GRAVITATION AND NEWTONS THIRD LAW OF MOTION**

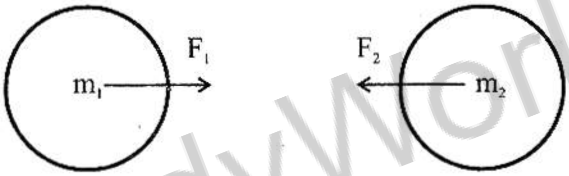
**By Newton's 3rd Law of Motion**

**Action and reaction are**

i. Equal in magnitude

ii. Opposite in direction

According to Law of gravitation mass "$m_1$" applies a force on mass "$m_2$" due to force of attraction. If the force $F_1$ acting on $m_1$ is considered as action then force acting on $m_2$ will be reaction. The action and reaction due to gravitation are equal in magnitude but opposite in direction as shown in figure. Hence law of gravitation and Newton's third law is inconsistence with each other.



$F_1 = F_2$

**Examples 5.1**

**Two lead spheres each of mass 1000 kg are kept with their centers 1 m apart. Find the gravitational force with which they attract each other.**

**Given data**

Here $m_1$ = 1000 kg
$m_2$ = 1000 kg
d = 1m
G = $6.673 \times 10^{-11}$ $Nm^2 kg^{-2}$

**Solution**

Since $F = G\frac{m_1m_2}{d^2}$

Putting the values, we get

$$F = 6.673 \times 10^{-11} \times \frac{1000 \times 1000}{(1)^2}$$

$$= 6.673 \times 10^{-11} \times 10^3 \times 10^3$$

$= 6.673 \times 10^{-11+3+3}$

$F = 6.673 \times 10^{-5}$ N

Thus, gravitational force of attraction between the lead spheres is $6.673 \times 10^{-5}$ N.

**Q5. How can you say that gravitational force is a field force?**

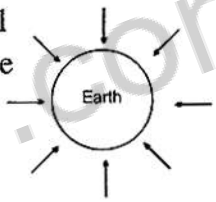
**Ans. Gravitational Field:-**

According to the Newton's law of gravitation, the gravitational force between a body of mass m and the earth is given by

$$F = G\frac{mMe}{r^2}$$

Where "$M_e$" is the mass of the Earth and r is the distance of the body from the centre of the Earth.

The weight of a body is due to the gravitational force with which the Earth attracts a body.



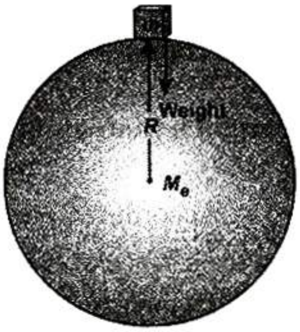
Gravitational force is a non-contact force. For example, the velocity of a body, thrown up, goes on decreasing while on return its velocity goes on increasing. This is due to the gravitational pull of the earth acting on the body which earth attracts the bodies towards its centre. Such, a force is called the field force. It is assumed that a gravitational field exists all around the Earth. This field is directed towards the centre of the Earth as shown by arrows in figure. The gravitational field force becomes weaker and weaker as we go higher and higher away from the Earth.

**Q6. What is gravitational field strength?**

**Ans.** In the gravitational field of the Earth, the gravitational force per unit mass is called the gravitational field strength of the Earth. At any place, its value is equal to the value of "g" at that point. Near the surface of earth, the gravitational field strength is 10 $Nkg^{-1}$

**Q7. Find the mass of earth by using the law of gravitation.**

**Mass of the Earth**



**Ans.** Consider a body of mass "m" is placed on the surface of the Earth. Let the mass of the Earth be "$M_e$" and radius of the Earth be "R". the distance of the body from the centre of the Earth will also be equal to the radius "R" of the Earth. According to the law of gravitation, the gravitational force "F" of the Earth acting on a body is given by

$$F = G\frac{mM_e}{R^2} \longrightarrow (1)$$

The force with which Earth attracts a body towards its centre is equal to its weight w.

$$F = w = mg \longrightarrow (2)$$

Comparing (1) and (2)

$$mg = G\frac{mM_e}{R^2}$$

$$\therefore\ g = G\frac{M_e}{R^2} \ \dots\dots \Rightarrow gR^2 = GM_e$$

and $\boxed{\frac{gR^2}{G} = M_e}$

Here $R = 6.4 \times 10^6 m$

$g = 10ms^{-2}$

$G = 6.673 \text{ x } 10^{-11} \text{ Nm}^2 \text{ Kg}^{-2}$

$$\text{So } M_e = \frac{(6.4 \times 10^6)^2 \times 10}{6.673 \times 10^{-11}}$$

$$= \frac{6.4 \times 6.4 \times 10^{12} \times 10}{6.673 \times 10^{-11}}$$

$$= \frac{6.4 \times 6.4 \times 10^{13+11}}{6.673}$$

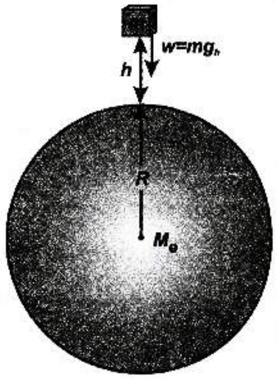
$$= \boxed{6 \times 10^{24} \text{ Kg}}$$

**Q8. How the value of 'g' varies with altitude?**

**Ans. Variation of g with altitude**

The value of "g" depends on the radius of the Earth at its surface.

Its value decreases as an object moves away from the surface of earth.



Consider a body of mass "m" is placed at an altitude "h" as shown in figure. The distance of the body from the center of the Earth becomes "R + h".

At height h from surface of earth $\boxed{g_h = \frac{GM_e}{(R+h)^2}}$

According to the above equation, we can calculate the value of "g" at any height "h" from the surface of earth.

The value of "g" is inversely proportional to the square of the radius of the Earth. But it does not remain constant. It decreases with altitude. The value of "g" is greater at sea level than at the hills.

### Example 5.2

Calculate the value of g, the acceleration due to gravity at an altitude 1000km. The mass of the Earth is $6.0 \times 10^{24}$ kg. The radius of the Earth is 6400km.

**Solution**

Here $R = 6400$ km
$h = 1000$ km
$M_e = 6.0 \times 10^{24}$ kg
$g_h = ?$
$R + h = 6400\text{ km} + 1000\text{ km} = 7400\text{ km}$
$= 7.4 \times 10^6$ m

As $g_h = G\dfrac{M_e}{(R+h)^2}$

$$g_h = \frac{6.673 \times 10^{-11} \times 6.0 \times 10^{24}}{(7.4 \times 10^6)^2}$$

$$= \frac{6.673 \times 6 \times 10^{24-11}}{7.4 \times 7.4 \times 10^{12}}$$

$$= \frac{40.038 \times 10^{13-12}}{54.76}$$

$$= 0.73 \times 10$$

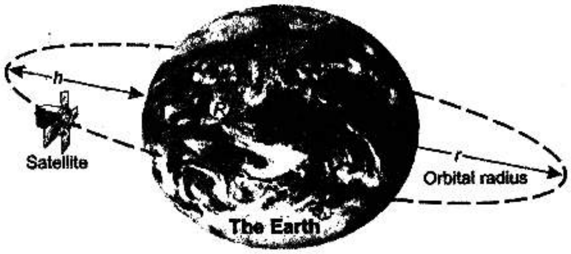
$= 7.3\text{ N kg}^{-1}$

$= 7.3\text{ ms}^{-2}$ Ans. $\because 1\text{Nkg}^{-1} = 1\text{ms}^{-2}$

**Q9. Define satellites. Find the orbital velocity of artificial satellites.**

**Ans.** An object that revolves around a planet is called satellite. Moon is natural satellite of our Earth. Some artificial satellites are revolving around the Earth which are used for communication and space research.

**Motion of artificial satellites**



Satellite revolving around earth

Consider a satellite of mass "m" revolving round the Earth at an altitude "h" in an orbit of radius "$r_o$". with orbital velocity "$v_o$". The necessary centripetal force which help the satellite to move around earth, which is provided by force of attraction between the satellite and earth is given by:

$$F_c = \frac{mv_o^2}{r_o} \quad \ldots\ldots\ldots..(1)$$

This force is provided by the gravitational force of attraction between the earth and satellite which is equal to the weight of satellite.

i.e $F_c = w' = mg_h$

Or $mg_h = \frac{mv_o^2}{r_o}$

or $v_o^2 = g_h \; r_o$

or $v_o = \sqrt{g_h \; r_o}$

as $r_o = R + h$

$$\therefore \; v_o = \sqrt{g_h \, (R+h)} \quad \ldots\ldots\ldots(1)$$

This is the velocity, which a satellite must possess when launched in an orbit of radius $r_o = (R + h)$ around the Earth. An approximation can be made for a satellite revolving close to the Earth such that R >> h. So *h* is negligible i.e $h \approx 0$.

Hence

$R + h \approx R$

and $g_h \approx g$

By putting the value of g and R in eq.(1) we will get.

$$\therefore \; v_o = \sqrt{g\,R} \;..$$

A satellite revolving around very close to the Earth, has speed "$v_o$"nearly 8 $kms^{-1}$ or 29000 $kmh^{-1}$.

## MULTIPLE CHOICE

**5.1. Encircle the correct answer from the given choice:**

**1. Earth's gravitational force of attraction vanishes at:**

(a) 6400km (b) infinity

(c) 42300 km (d) 1000 km

**2. Value of g increases with the:**

(a) increase in mass of the body

(b) increase in altitude

(c) decrease in altitude

(d) none of the above

**3. The value of g at a height one Earth's radius above the surface of the Earth is:**

(a) 2 g (b) $\frac{1}{2}$ g

(c) $\frac{1}{3}$ g (d) $\frac{1}{4}$ g

**4. The value of g on moon's surface is 1.6 ms$^{-2}$. What will be the weight of a 100 kg body on the surface of the moon?**

(a) 100 N (b) 160 N
(c) 1000N (d) 1600N

**5. The altitude of geostationary orbits in which communication satellites are launched above the surface of the earth is:**

(a) 850 km (b) 1000 km
(c) 6400 km (d) 42, 300 km

**6. The orbital speed of a low orbit satellite is:**

(a) zero (b) 8 ms$^{-1}$
(c) 800 ms$^{-1}$ (d) 8000 ms$^{-1}$

**7. The first man who gave the idea of gravity:**

(a) Hero (b) Einstein
(c) Newton (d) Faraday

**8. Earth revolves around the:**

(a) Moon (b) Sun
(c) Galaxy (d) None

**9. Law of Gravitation is consistence with:**

(a) 1st Law of motion
(b) 2nd Law of motion
(c) 3rd Law of motion
(d) Ohm's Law

**10. Gravitational force is a:**

(a) Electric force
(b) Magnetic force
(c) reactional force
(d) electromotive force

**11. Near the earth surface, the gravitational field strength is:**

(a) 1N kg$^{-1}$ (b) 100 Nkg$^{-1}$
(c) 10 Nkg$^{-1}$ (d) 101Nkg$^{-1}$

**12. Mass of earth is equal to:**

(a) 7.1 x 10$^{24}$kg (b) 6.0 x 10$^{24}$kg
(c) 6.5 x 10$^{24}$ kg (d) 9.1 x 10$^{24}$ kg

**13. The value of 'g' on the surface of moon is:**

(a) 1.62 ms$^{-2}$ (b) 10ms$^{-2}$
(c) 20ms$^{-2}$ (d) zero

**14. The value of 'g' on the surface of Mars:**

(a) 3.73 ms$^{-2}$ (b) 1.62 ms$^{-2}$
(c) Zero (d) constant

**15. The value of 'g' is greater at:**

(a) moon (b) Hills
(c) sea level (d) desert

**16. The velocity of geostationary satellites with respect to the earth is**

(a) maximum (b) Zero
(c) minimum (d) 100ms$^{-1}$

**17. Moon is our satellite:**

(a) artificial (b) permanent
(c) natural (d) communication

**18. GPS system consist of earth satellites:**

(a) 4 satellites (b) 24
(c) 20 (d) 30

**19. Orbital velocity V$_o$ =:**

(a) $\sqrt{gR}$ (b) $\sqrt{RG}$
(c) gR (d) gR$^2$

**20. Moon is nearly km away from the Earth:**

(a) 3,80,000km (b) 3800 km

(c) 3,80 km (d) 38 km

**21. A satellite revolving around very close to earth has speed nearly:**

(a) 5 $kms^{-1}$ (b) 8 $kms^{-1}$
(c) 10$kms^{-1}$ (d) 100$kms^{-1}$

**22. The Earth attracts a body with a force equal to its:**

(a) velocity (b) gravity
(c) weight (d) mass

**23. The value of gravitational constant "G" is $Nm^2kg^{-2}$:**

(a) $6.67 \times 10^{-21}$ (b) $6.67 \times 10^{-11}$
(c) $6.67 \times 10^{-23}$ (d) $6.67 \times 10^{11}$

**24. The unit of gravitational constant is:**

(a) $Nm^2kg$ (b) $Nm^2kg^{-2}$
(c) $Nm^2kg^{-1}$ (d) $N\text{–}m^2$

**25. Moon completes its revolution around earth in days:**

(a) 22 (b) 23
(c) 27.3 (d) 25

## ANSWERS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.** | b | **2.** | c | **3.** | d | **4.** | b | **5.** | d |
| **6.** | d | **7.** | c | **8.** | b | **9.** | c | **10.** | c |
| **11.** | c | **12.** | b | **13.** | a | **14.** | a | **15.** | c |
| **16.** | b | **17.** | c | **18.** | b | **19.** | a | **20.** | a |
| **21.** | b | **22.** | c | **23** | b | **24** | b | **25** | c |

## SHORT QUESTIONS

**Q.1 What is meant by force of gravitation?**

**Ans.** The force due to which every object in the universe attracts every other object i called force of gravitation.

**Q.2 What is a field force?**

**Ans.** The gravitational pull of earth acting on a body whether the body is in contact wit earth or not is called field force.

**Q.3 How can you say that gravitational force is a field force?**

**Ans.** We can say that gravitational force is field force. To understand it consider a bod which is thrown vertically upward we observe its velocity which is continuously decreasin in upward direction and the body which is falling continuously increasing its velocity i downward direction. This is due to gravitational pull of the earth. This shows tha gravitational force is field force.

**Q.4 Explain, what is meant by gravitational field strength?**

**Ans.** In the gravitational field of the Earth, the gravitational force per unit mass is calle the gravitational field strength of the Earth. Gravitational field strength is greater on th surface of earth but as we go higher from surface of earth, its value decreases.

**Q.5 Why does the value of "g" vary from place to place?**

**Ans.** Since the value of "g" varies with altitude so its value is different at different places.

**Q.6 Explain how the value of "g" varies with altitude?**

**Ans.** As we go higher, the value of "g" becomes less and as we move towards earth its value increases which can be calculated by the formula $g_h = \frac{GM}{(R+h)^2}$

**Q.7 How Newton's law of gravitation helps in understanding the motion of satellites?**

**Ans.** To keep the satellite move in circular orbit centripetal force is necessary which is supplied by the gravitational force of attraction between earth and satellite.

**Q.8 On what factor the orbital speed of a satellite depends?**

**Ans.** The orbital speed of satellite depends upon the altitude.

$$\text{Since} \quad V_{orb} = \sqrt{\frac{GM}{(R+h^2)}}$$

Where h is altitude

**Q.9 Why communication satellites stationed at geostationary orbits?**

**Ans.** Since Earth completes its one rotation in 24 hours and communication satellites also take 24 hours to complete its one round. So communication satellites are stationary with respect to Earth. So they are called geostationary satellite.

**Q.10 Can you determine the mass of our moon? If yes, then what do you need to know?**

**Ans.** Yes, Mass of moon can be determine by the following formula.

$$M_m = \frac{g_m R_m^2}{G}$$

In this equation '$g_m$' is the gravitational acceleration on the surface of moon and 'G' is gravitational constant. If we know the radius of moon, then we can find the mass of moon by using this relation.

**Q.11 Why is law of Gravitation important to us?**

**Ans.** Law of Gravitation is very important to us because it tells about the force of attraction between the objects. It also explains how this force decrease as we go upward from the surface of Earth. This gravitation force is directly Proportional to the masses of the objects and inversely proportional to the square of distance between them.

It also explains the motion of the planets in the solar system. By using the law of gravitation we can find the mass of earth. It also helps to understand the motion of satellites.

**Q.12 Why earlier scientists could not guess about the gravitational force?**

**Ans.** The earliest Greek scientist could believe that Earth remain stationary at the center while planets including sun and Moon revolve around it. In 16th century another theory was explained. In which Sun is stationary at the center and Earth and planets revolve around it in different orbits. To resolve the conflict between these theories Newton explained the theory of gravity and law of Gravitation.

**Q.13 Does an apple attract the earth towards it?**

**Ans.** The mass of an apple is very very small as compare to mass of Earth. According to law of gravitation, gravitational force is directly proportional to masses of the objects so, apple will attract the Earth with equal force as earth but attractive force of dominate the attractive force of apple.

**Q.14 What is GPS?**

**Ans.** Global positioning System (GPS) is satellites navigation system. It helps us to find the exact position of an object anywhere on the land, on the sea or in the air. GPS consists of 24 Earth satellites. These satellites revolve around the Earth twice a day with a speed of 3.87 $kms^{-1}$.

**Q.15 Do you attract the Earth or earth attracts you? Which one is attracting with a larger force? You or the earth.**

**Ans.** As gravitational force is directly proportional to the product of masses so, we cannot attract the earth with a force but if we are freely falling then Earth attract us towards it's centre. The force of attraction of Earth is much greater as compared to us. So we cannot attract the earth.

**Q.16 With what force an apple weighing 1N attracts the Earth?**

**Ans.** The force of the apple is also 1N.

**Q.17 Does the weight of an apple increase, decrease or remain constant when taken to the top of a mountains?**

**Ans.** The weight of an apple decreases when taken to the top of a mountain because the value of $g$ decreases as the altitude increases.

**Q18. What is satellite? What are their kinds?**

**Ans.** An object that revolves around a planet is called a satellite. Its of two types.

**(i) Artificial satellite (ii) Natural satellite**

**Q.19 What is the height of geostationary satellites?**

**Ans.** The height of a geostationary satellite is about 42,300 km from the surface of the Earth. Its velocity with respect to Earth is zero.

**Q.20 Why communication satellites are geostationary satellite?**

**Ans.** Communication satellites take 24 hours to complete their one revolution around the Earth. As Earth also completes its one rotation about its axis in 24 hours, hence, these communication satellites appear to be stationary with respect to Earth. It is due to this reason that the orbit of such a satellite is called geostationary satellite. Dish antennas sending and receiving the signals from them have fixed direction depending upon their location on the Earth.

**Q.21 How far moon is from earth and in how much time it complete its rotation?**

**Ans.** Moon is nearly 3,80,000 km away from the Earth. It completes its one revolution around the Earth in 27.3 days.

## NUMERICAL PROBLEMS

**5.1. Find the gravitational force of attraction between two spheres each of mass 1000 kg. The distance between the centers of the spheres is 0.5 m.**

**Given Data**

Mass of first sphere $= m_1 = 1000$ kg

Mass of second sphere $= m_2 = 1000$ kg

The distance between their centers $= d = 0.5$m

Gravitational force $= F = ?$

Gravitational constant

$G = 6.673 \times 10^{-11}\ Nm^2\ kg^{-2}$

**Solution**

$$F = G\frac{m_1 m_2}{d^2}$$

$$= \frac{6.673 \times 10^{-11} \times 1000 \times 1000}{(0.5)^2}$$

$$F = \frac{6.673 \times 10^{-5}}{0.25}$$

$$F = 26.69 \times 10^{-5}$$

$F = 2.67 \times 10^{-4}$N **Ans.**

**5.2. The gravitational force between two identical lead spheres kept at 1 m apart is 0.006673 N. Find their masses.**

**Given data**

Gravitational force $= F = 0.006673$ N

Distance between two identical spheres

$d = 1$m

Masses of identical sphere $= m_1 = ?$

Gravitational Constant

$G = 6.673 \times 10^{-11}\ Nm^2\ kg^{-2}$

**Solution**

Let us suppose two spheres are identical

So

$m_1 = m_2 = m$

**Solution**

$$F = G\frac{m_1 m_2}{d^2}$$

$$m_1 = m_2 = m$$

$$F = G\frac{m \times m}{d^2}$$

$$Gm^2 = Fd^2$$

$$\sqrt{m^2} = \sqrt{\frac{Fd^2}{G}}$$

$$m = \sqrt{\frac{0.006673 \times 1}{6.673 \times 10^{-11}}}$$

$$= \sqrt{\frac{0.006673 \times 10^{11}}{6.673}}$$

$$= \sqrt{\frac{6673 \times 10^{11} \times 10^{3}}{6673 \times 10^{6}}}$$

$$= \sqrt{\frac{10^{11+3}}{10^{6}}}$$

$$= \sqrt{10^{14-6}}$$

$$= \sqrt{10^{8}}$$

$$= \sqrt{(10^{4})^2}$$

$$m = 10,000 \text{ kg}$$

**Since** $m_1 = m_2$

$m_1 = 10{,}000\text{kg}$

$m_2 = 10{,}000\text{kg}$

Each sphere has mass 10,000 kg.

**5.3. Find the acceleration due to gravity on the surface of the Mars. The mass of Mars is 6.42 x$10^{23}$ kg and its radius is 3370 km.**

**Given data**

Mass of Mars = M = $6.42 \times 10^{23}$ kg

Radius of Mars = R = 3370 km

$R = 3370 \times 10^3\text{m}$

Gravitational constant

$G = 6.67\times10^{-11}\ \text{Nm}^2\text{kg}^{-2}$

Gravitational acceleration = g = ?

**Solution**

$$g = \frac{GM}{R^2}$$

$$= \frac{6.67\times10^{-11}\times6.42\times10^{23}}{(3370\times10^3)^2}$$

$$= \frac{42.84066\times10^{23-11}}{11356900\times10^6}$$

$$= \frac{42.84066\times10^{12-6}}{11356900}$$

$$= 0.000003772\times10^6$$

$$= 3.77\ \text{ms}^{-2}$$

$$g = 3.77\text{ms}^{-2}$$

**5.4. The acceleration due to gravity on the surface of moon is 1.62 ms$^{-2}$. The radius of Moon is 1740 km. Find the mass of moon.**

**Given Data**

Acceleration due to gravity on the surface of moon = $g_m$ = $1.62\ \text{ms}^{-2}$

The radius of Moon

$R_m = 1740\ \text{km} = 1740 \times 10^3\ \text{m}$

Gravitational constant

$G = 6.673 \times 10^{-11}\ \text{Nm}^2\text{kg}^{-2}$

Mass of Moon = $M_m$ = ?

**Solution**

We know that

$$M_m = \frac{gR^2}{G}$$

$$M_m = \frac{1.62\times(1740\times10^3)^2}{6.673\times10^{-11}}$$

$$= \frac{1.62\times3.027600\times10^6}{6.673\times10^{-11}}$$

$$= \frac{4.904712\times10^6}{6.673\times10^{-11}}$$

$$735008.5\times10^{17}$$

$$M_m = 7.35 \text{ x } 10^{22}\ \text{kg}$$

Mass of moon = $7.35 \text{ x } 10^{22}$ kg

**5.5. Calculate the value of g at a height of 3600 km above the surface of the Earth.**

**Given data:**

Hight = h = 3600 km

$h = 3600 \times 10^3\text{m} \Rightarrow 3600000\text{m}$

$R = 6.4 \times 10^6\text{m}$

$G = 6.673 \times 10^{-11}\ \text{Nm}^2\text{kg}^{-2}$

$M = 6 \times 10^{24}\text{kg}$

**Solution:**

$$g_h = \frac{GM}{(R+h)^2}$$

$$= \frac{6.673\times10^{-11}\times6\times10^{24}}{(3600000+6.4\times10^6)^2}$$

$$= \frac{40.038\times10^{24-11}}{(3.6\times10^6+6.4\times10^6)^2}$$

$$= \frac{40.038\times10^{13}}{(10^7)^2}$$

$$= \frac{40.038\times10^{13}}{10^{14}}$$

$$= 40.038\times10^{14-13}$$

$$= \frac{40.038}{10^{14-13}} = \frac{40.038}{10}$$

$$g_h = 4.0\ ms^{-2}$$

**5.6. Find the value of g due to the Earth at geostationary satellite. The radius of the geostationary orbit is 48700 km.**

**Given Data:**

Radius of the geostationary orbit

$$R = 48700\ km$$

$$R = 48700\times10^3$$

$$G = 6.673\times10^{-11}\ Nm^2kg^{-2}$$

Mass of earth = $M = 6\times10^{24}$ kg

**Solution**

$$g = \frac{GM}{R^2}$$

$$g = \frac{6.673\times10^{-11}\times6\times10^{24}}{(48700000)^2}$$

$$= \frac{40.038\times10^{24-11}}{(487)^2\times(10^5)^2}$$

$$= \frac{40.038\times10^{13}}{2371069\times10^{10}}$$

$$= 0.00016\times10^{13-10}$$

$$= 0.00016\times10^3$$

$$= 0.1688ms^{-2}$$

$$g = 0.17\ ms^{-2}$$

**5.7. The value of g is 4.0 ms$^{-2}$ at a distance of 10000 km from the centre of the Earth. Find the mass of the Earth.**

$$g = 4ms^{-2}$$

Height= $h = 10000km$

$$h = 10000\times10^3m$$

$$h = 10^7m$$

Mass of earth = $M_e = ?$

$G = 6.673\times10^{-11}Nm\ Kg^{-2}$

**Solution:**

$$g = \frac{GM_e}{R^2}$$

$$M_e = \frac{gR^2}{G}$$

$$= \frac{4\times(10000000)^2}{\left(6.673\times10^{-11}\right)}$$

$$= \frac{4\times(10^7)^2}{6.673\times10^{-11}}$$

$$= \frac{4\times10^{14}}{6.673\times10^{-11}}$$

$$= 0.599\times10^{14+11}$$

$$= 0.5999\times10^{25}$$

$$= 5.99\times10^{-1}\times10^{25}$$

$$M_e = 5.99\times10^{24}\ kg$$

**5.8. At what altitude the value of g would become one fourth than on the surface of the earth?**

**Given Data**

Altitude = h = ?

$$g_h = \frac{g}{4}$$

**Solution**

We know that

$$g = \frac{GM}{R^2} \ldots\ldots(1)$$

If radius is doubled then R = 2R so equation (1) becomes

$$g_h = \frac{GM}{(2R)^2}$$

$$g_h = \frac{GM}{4R^2}$$

$$4g_h = \frac{GM}{R^2}$$

Using equation (1)

$$4g_h = g$$

So $g_h = g/4$ **(i.e one earth's radius)**

**5.9. A polar satellite is launched at 850 km above Earth. Find its orbital speed.**

**Given Data:**

Height = $h = 850\text{ km}$

$h = 850 \times 10^3\text{m}$

$G = 6.673 \times 10^{-11}\text{ Nm}^2\text{kg}^{-2}$

$Me = 6 \times 10^{24}\text{ kg}$

$V_{orb} = ?$

**Solution**

$$g_h = \frac{GM_e}{(R+h)^2}$$

$$= \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(6.4 \times 10^6 + 850000)^2}$$

$$= \frac{40.038 \times 10^{24-11}}{(6400000+850000)^2}$$

$$= \frac{40.038 \times 10^{13}}{(7250000)^2}$$

$$= \frac{40.038 \times 10^{13}}{525625 \times 10^8}$$

$$= \frac{40.038 \times 10^{13-8}}{525625}$$

$$= 0.00076172 \times 10^5$$

$$g_h = 7.6172\text{ ms}^{-2}$$

Now $V_0 = \sqrt{g_h(R+h)}$

$$= \sqrt{7.6172 \times (6.4 \times 10^6 + 850000)}$$

$$= \sqrt{7.6172 \times (6400000 + 850000)}$$

$$= \sqrt{7.6172 \times 7250000}$$

$$= \sqrt{55224700}$$

$$= 7431\text{ms}^{-1}$$

**5.10. A communication satellite is launched at 42000 km above Earth. Find its orbital speed.**

**Given data**

$h = 42000\text{km}$

$h = 4200 \times 10^3\text{m}$

Mass of earth = $M_e = 6 \times 10^{24}\text{Kg}$

$G = 6.673 \times 10^{-11}\text{ Nm}^2\text{ Kg}^{-2}$

$V_{orb} = ?$

**Solution:**

$$g_h = \frac{GM}{(R+h)^2}$$

$$= \frac{6.673\times10^{-11}\times6\times10^{24}}{(6.4\times10^{6}+42000000)^{2}}$$

$$= \frac{40.038\times10^{24-11}}{(6400000+42000000)^{2}}$$

$$= \frac{40.02\times10^{13}}{(48400000)^{2}}$$

$$= \frac{40.038\times10^{13}}{234256\times10^{10}}$$

$$= 0.000171\times10^{13-10}$$

$$g_h = 0.000171\times10^{3}$$

$$g_h = 0.171\,ms^{-1}$$

Now

$$V_o = \sqrt{g_h\,(R+h)}$$

$$V_o = \sqrt{0.171(6.4\times10^{6}+42000000)}$$

$$V_o = \sqrt{0.171(48400000)}$$

$$= \sqrt{8276400}$$

$$= 2876\,ms^{-1}$$